



# THE BOSTON ATHENÆUM

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## **White Paper**

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Title of project: Review of the Boston Athenæum Climate Control Systems for Optimization and Sustainability

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Institution: Boston Athenæum

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## **Narrative Description**

Founded in 1807, The Boston Athenaeum is one of the oldest cultural institutions in the United States. Its large, important, and varied collections form an essential resource for those studying the history or culture of Boston, New England, and the United States. It is housed in a mid-19th-century National Landmark Building extensively renovated at the turn of the 21st century with a modern climate control system. There, collections share space with the public, staff, members, researchers, and scholars. This diverse profile presents special challenges for climate control and collections preservation.

Inconsistent data from sensors and a hand-held, hygrothermograph monitoring device in conjunction with an ageing HVAC system led to the current study. The Athenaeum team partnered with consultants from the Image Permanence Institute and worked towards two goals: investigating current environmental mechanical systems which are providing inconsistent data on temperature and humidity and optimizing the systems for efficiency and sustainability, leading to better conditions for our materials, energy savings, and a better use of resources.

## **Project background**

In the 1980's, a basic climate control system was installed in the Athenaeum's rare collection storage and in the rare book reading room. During the extensive 1999-2002 renovation, the Athenaeum building was equipped with ten TEMTROL air-handling units (AHUs). One AHU is a single zone unit dedicated to one area; two Texas multi-zone units with a humidifier for each zone, and eight with a single humidifier for all zones. There are two McQuay chillers each with 250 ton capacity, only one is in use at a time, and two cooling towers, 250 nominal tons each manufactured by BAC, (Baltimore Aircoil Company). Sensors throughout the building monitor the system. Information about the environment is accessed, monitored, and managed through Siemens APOGEE software. Some poorly placed sensors in spaces provide conflicting information and there were no sensors in 6 of the locked room spaces. These spaces are checked frequently with hand held hygrothermographs. The spaces were not monitored by traditional data loggers.

During 1999-2002 renovation there were expansions into portions of 14 Beacon Street next door. But the main focus of the study was the investigation of the HVAC systems that service the 10 1/2 Beacon Street building and owned and leased space in 14 Beacon Street. (An additional leased suite of three offices at 14 Beacon Street do not contain collection material and are not serviced by the 10 1/2 Beacon systems.)

To meet the eclectic needs of the building, collections, and audiences, HVAC zone settings have been established, each with summer and winter parameter recommendations for temperature and humidity:

### **1. Rare collection materials in unoccupied spaces:**

Summer: 50% +/- 5% RH; temperature below 63°F

Winter: 45% +/- RH; temperature below 63°F

### **2. Rare collection material in occupied spaces:**

Summer: 50% +/- RH; temperature averages 73°F

Winter: 45% +/- 5% RH; temperature averages 70°F

### **3. Open shelf collection material in occupied spaces:**

Summer: 50% +/- 10% RH; temperature averages 73°F

Winter: 45% +/- 10% RH; temperature averages 70°F

### **4. Spaces with no collection materials:**

No specified preservation settings

For this 24-month study, three AHUs were identified that are representative of the building's environments and mechanical systems:

AHU-A servicing rare collection materials in unoccupied spaces

AHU-I servicing open shelf materials/rare materials in occupied spaces

AHU-J servicing rare collection materials in occupied spaces.

Before the study, nightly shutdowns of the HVAC system during seasonably mild weather was not uncommon. (HVAC runs continuously during peak summer and winter periods).

The locations of the Siemens sensors associated with the above AHUs and zones were identified, and their significance in obtaining and providing significant data was one of the goals of this plan. Twenty-eight zones were identified for data logger monitoring and analysis; some of these data loggers were placed near current Siemens sensors, while others were placed in areas that were currently not being monitored.

## **Project Activities**

Over the course of the past year and a half personnel changes have resulted in revisions to the list of the original participants in the project. The Boston Athenæum's Deputy Director, James Reid-Cunningham, and Associate Director and Curator of Maps, John Lannon, Facilities Director, Mike Pagliaro, have left the institution. Christopher Silva was hired as the Director of Facilities at the end of August 2017. Robert West, the Director of Operations, and Will Evans, National Endowment for the Humanities Chief Librarian in Charge of Technical Services at the BA, have joined the project team. Additionally, the Preventive Conservation Specialist at the Image Permanence Institute, Kelly McCauley Kirsh, has also joined the project team. While in August of 2017, Jeremy Linden, Senior Preservation Environment Specialist, Image Permanence Institute, left the Image Permanence Institute. The current project participants are as follows:

- Elizabeth Barker, PhD., Stanford Calderwood Director, Boston Athenaeum (project team and project co-manager)
- Robert West, Director of Operations, Boston Athenaeum (project team and project co-manager)
- Dawn Walus, Chief Conservator, Boston Athenaeum (project team and project director)
- Christopher Silva, Director of Facilities, Boston Athenaeum (project team)
- Stanley Cushing, Anne C. Bromer and David J. Bromer Curator of Rare Books and Manuscripts, Boston Athenaeum (project team)
- Will Evans, National Endowment for the Humanities Chief Librarian in Charge of Technical Services, Boston Athenaeum (project team)
- Philip Edwards Phillips, PhD., professor of English, Associate Dean, University Honors College, Middle Tennessee State University; President, Poe Studies Association (letter of support)

- Richard J. Boes, PhD., visiting Assistant Professor, The City College of New York (letter of support)
- Christopher Cameron, Sustainable Preservation Specialist, Image Permanence Institute (consultant)
- Kelly McCauley Krish, Preventive Conservation Specialist, Image Permanence Institute (consultant)

The in-house BA team worked closely with the IPI consultants. The consultants made three site visits over the course of the project.

During the initial visit in October 2015, the BA project team met with the IPI consultants to discuss the project objectives, which was to identify data and mechanical discrepancies. In addition, the three air AHUs chosen for the study and the spaces they service were examined and documented; PEM2 data-loggers (PEMs) were deployed in the spaces and in AHUs (some were installed within the mechanical units); data was retrieved from the PEMs; training was performed on the eClimateNotebook software.

Data from PEMs was downloaded and uploaded into eClimateNotebook every month during the 24-month study period.

During the second site visit in July 2016, over six months of data that had been captured was collected and analyzed; documentation on PEMs locations was created; the duct work from the AHUs to the areas they service within the collections was tracked; and data from RTU-1 and AHU-A was analyzed; and their findings were presented to the BA project team.

Experiments were undertaken throughout the 24-month period.

#### Experiment 1: Cooling coil set point adjustment (dehumidification season)

The following explanation of this experiment is culled from IPI scope of work:

Data collected in mechanical systems and collection spaces at the Boston Athenaeum since October 2015 shows that the cooling coil at AHU A performs more sensible cooling than necessary in dehumidification seasons. This data suggests that it may be possible to implement changes in the operation of the Athenaeum's mechanical system that would achieve greater energy savings while maintaining preservation goals in collection spaces. Based on this current understanding of the mechanical system operation, as well as discussion with staff and contractors, IPI proposes to change the discharge air temperature set point on the cooling coil at AHU A from 50°F to 58°F for a two-week experiment. This experiment should take place this September- October (the exact date to be selected by the Boston Athenaeum) while the system is still in a period of dehumidification. It is believed that this change will result in a reduced sensible temperature workload at the cooling coil. The balancing dampers between the hot and cold decks should modulate to provide adequate supply air temperatures to maintain current set points in the spaces.

To monitor the experiment, the following should occur:

- The conservator will undertake a daily walkthrough of the spaces and spot check dataloggers for inappropriate temperature and relative humidity conditions;

- At the one-week interval and at the two-week completion of the experiment, data will be downloaded from the dataloggers and uploaded to eClimateNotebook for analysis by team members;
- And follow up discussion will take place between interested parties to evaluate the success of the experiment in providing appropriate and sustainable preservation environments.

The results of this discussion will determine whether or not the Boston Athenaeum is interested in continuing to build on such experimentation throughout the remainder of the project.

### Experiment 2: Relative humidity set point adjustment

Again, the experiment as outlined in the IPI scope of work:

Data collected in collection spaces at the Boston Athenaeum since October 2015 shows that the locked rooms receive more humidification than is necessary or desired in the winter season, resulting in an excess expenditure on steam humidification and possible exacerbation of building envelope issues. This data suggests that it may be possible to implement changes in the operation of the Athenaeum's mechanical system that would achieve greater energy savings while maintaining preservation goals in collection spaces. Based on this current understanding of the mechanical system operation, as well as discussion with staff and contractors, IPI proposes to change the relative humidity set point for the locked rooms from 45%RH in winter (which results in 45-60%RH in the spaces) to 35%RH (with the goal of 35-50%RH in the spaces) for a two-week experiment. This experiment should take place this January- February (the exact date to be selected by the Boston Athenaeum) while the system is still in a period of humidification. It is believed that this change will result in a reduced humidification workload at the unit and lower %RH in the spaces. While the %RH should still be within a safe range to prevent mechanical damage to materials in the spaces, there will be a lower risk of mold (a high %RH on a cold exterior wall could have played a role in its appearance) and building envelope issues.

To monitor the experiment, the following should occur:

- The conservator will undertake a daily walkthrough of the spaces and spot check dataloggers for inappropriate relative humidity conditions, as well as take surface temperature readings and look for evidence of mold/envelope issues on exterior walls;
- At the one-week interval and at the two-week completion of the experiment, data will be downloaded from the dataloggers and uploaded to eClimateNotebook for analysis by team members and comparison with Siemens sensors;
- And follow up discussion will take place between interested parties to evaluate the success of the experiment in providing appropriate and sustainable preservation environments.

The results of this discussion will determine whether or not the Boston Athenaeum is interested in continuing to build on such experimentation throughout the remainder of the project.

Also at this time, the set point in the Vershbow Special Collections Reading Room (served by AHU-J, 5J) was changed from 73°F to 71°F, after the study revealed that temperatures in this room were reaching as high as 76°F, a temperature deemed much too high for a low occupancy space containing special collection materials.

During the third visit August 2017, project objectives and methods were reviewed, data was pulled from the 3 AHUs and spaces, the data was reviewed and analyzed, some recommendations were made and next steps were discussed.

### **Observations, Recommendations, Actions**

At the end of the study period, the IPI consultants submitted a detailed final report of the mechanical design and operation of the three AHUs chosen for the study, and outlined overall goals and suggestions. Following is a summary of the observations and recommendations made by IPI and the actions to be taken/taken by BA staff.

#### **Short Term Recommendations:**

1. Provide adequate clearance and airflow: some instances of grilles and supply diffusers blocked by items and compact shelving. Relocation of materials and compact shelving open at supply diffusers to allow adequate air flow.
2. Address the supply air issue on AHU I: daily temperature fluctuations of 3-5°F roughly between the hours of 8am and 5pm through winter may indicate a problem in downstream reheats. Replacement of the chiller and sealing the duct work on the roof that is scheduled for the winter 2018 will solve this problem.
3. Try to mitigate the light load: there is heat generated by the type and number of interior lighting sources. Incandescent lights are being replaced LED lights and motion sensors installed in some areas (restrooms). An assessment of window coverings has been and this is an area in much need of improvement. Possible implementation grant.
4. Add sensors for improved monitoring: lack of temperature and humidity sensors in 6 of the locked room spaces. The BA is using the \$10,000 of implementation money from this grant towards purchasing and installing additional sensors in the locked room spaces that previously were not monitored.
5. Use seasonal temperatures where appropriate: lower temperatures used in winter to improve preservation and not artificially lowering the relative humidity. However, care should be taken in using this technique, without an improved building envelope that can provide protection against thermal and moisture differences between these spaces and others, as well as the exterior of the building. Improving the building envelope is being engineered with many improvements to begin in the winter of 2018. See also “Long Term Recommendations #1”.
6. Reduce winter humidification: in winter, the units are trying to hold relative humidity higher than necessary. We will reduce relative humidity to 35 % - 50% (+/- 5) during winter months. December 15<sup>th</sup> – February (?) Defining the winter months to be determined.
7. Perform an air balancing study. It is nearly impossible to know the adjustments that have been made in the years since the mechanical systems were installed. Performing air balancing will improve air delivery and distribution as well as positive or neutral pressurization in rooms. Air balancing in the building has begun as of October 2017.

### Long Term Recommendations:

1. Determine moisture issues in the Lock Room: an exterior masonry wall in one the locked room spaces, 3G East, has been plagued with moisture issues. The Athenaeum has taken a few measures to try to alleviate this problem: increased temperatures, the use of fans, and removal of the books from against the wall. Unfortunately, none of these have proven successful as long-term approaches. Making sure the roof drains are open and free flowing and installing a moisture or an insulating barrier at the masonry wall in the 3G locked room could eliminate the moisture issues. BA staff identified that the roof drains were blocked and not allowing rain water to leave the roof and was causing water to back up into the building. As of November 2017, the gutters and downspouts have been replaced. Building a moisture/insulating barrier in the 3G East locked room space is being engineered and is scheduled to begin in the winter of 2018.

Regardless of the Athenaeum's long-term plans, addressing the moisture issue in this room will be critical because it preserves the building envelope. If this space continues to serve as storage, installing a vapor barrier will allow for a lower dew point to be safely used, with lower temperatures and controlled relative humidity to benefit the other collection materials. Without it, lowering the dew point will speed up the diffusion process and exacerbate the moisture issues on the walls.

2. Determine the cause of the high dew point from RTU 1: regrettably, the air from RTU 1 is not arriving at the units with a low dew point. Because of this, the air is arriving at the unit with a dew point that is almost the same as the return air. This is causing the cooling coil to act as the primary source of dehumidification. The reason for the lack of low dew point should be identified to help improve the overall dew point of the facility and allow the units downstream to create a better preservation environment. RTU-1 is not operating properly due to the ducts off RTU-1 being too close to the ground (roof) and are not insulated properly. Also, that there may be leaks in the ducts allowing water to infiltrate and not able to maintain proper dew point. This problem will be remedied during roof repairs scheduled for winter 2018. When this is resolved, it will hopefully improve the dew point of the RTU 1 supply air downstream.

3. Evaluate the cooling coils: The dew point for most of the facility should be dictated by the dew point off of RTU 1 and the air from RTU 1 is not arriving with a reliable dew point. As a result, the cooling coils on the individual units have become responsible for moisture removal of the passing air. The reason for the low dew point on the current coils may be the result of one of many issues: the coils may be congested inside, the fins of the coils may be plugged with debris, the chiller may not be functioning properly, or the coil on the units may simply have not been designed to provide a better dew point. Also, not able to maintain dew point due to water leakage in pre air and return air duct work for RTU 1. A new chiller will resolve this problem and the cooling coils will be cleaned and readjusted in winter 2018.

4. Reduce excess sub-cool/ reheat operation: both AHU A and AHU I appear to use more cool air than necessary to meet supply air conditions. This means additional work is being performed by the reheats downstream to recover the temperature. Adjusting the discharge air set point temperature off the cooling coils to be the minimum necessary to provide the desired preservation conditions in the spaces will result in more efficient operation and energy savings. This change will potentially reduce the amount of cooled air used and limit the reheat operation. New chiller will resolve this problem?

5. Resume shutdowns: when the new BMS has been installed, the Athenaeum should consider reinstituting the use of nightly shutdowns. The Athenaeum should test the shutdowns to ensure that the new equipment can perform these operations and that the staff are comfortable with the results. The test should range from 6 to 8 hours nightly for two weeks and monitored by dataloggers and analyzed daily during test period ensuring that there are no temperature fluctuations greater than 2-3°F during the course of the shutdown. During this time, the system is completely shut down and the outside air remains closed. This will test the ability of the spaces served by the AHU to hold the temperature against any heating or cooling loads within the space. The shutdown tests should be performed twice, once in the summer (July/September) and once in the winter (December/March). Instituting 8-hour/day shutdowns would reduce energy consumption by each unit by roughly 33%. According to the BA Director of Facilities, with the mechanicals in their present state, nightly shutdowns would not allow for effective troubleshooting and would result in minimal cost savings.

6. Consider utilizing the VFDs on the units more: all of the units have a variable frequency drive (VFD) installed on them. However, due to inefficient communication with the BMS system, the drives are not utilized. The VFD can allow the speed of the fans to be matched with the load requirements. When the facility does not need to operate at peak load conditions, the fans can slow down and use less energy. This problem is related to issue #2. The fans are trying to keep up with moving drier air into the spaces, so the units are under load constantly. Once issue outline in #2 is resolved, the units will not have to be under load and the VFDs will be used as designed.

7. Reduce the number of air filters on AHU A: study found excessive filtering. Currently, there are 4 sets of filters located after the mixed air in the A unit, but this air is already filtered by the RTU-1 unit on the roof. It is possible that such extreme filtration is not needed and could save the cost of replacing the filters. Because of our location in the city, Director of Facilities stated that the spaces require the additional filtering and requests they stay in place.

### **Accomplishments**

The project accomplished the two main stated goals: the implementation of data loggers in strategic areas throughout the building yielded consistent data on temperature and humidity, and by analyzing that data, the Boston Athenæum was able to expand environmental parameters while maintaining a preservation environment. Thus, the institution was able to better optimize its systems for greater efficiency and sustainability, leading to better conditions for its materials, energy savings, and a more prudent use of resources.

### **Audiences**

AIC Annual Meeting, New England Conservation Association (NECA) and/or International Association of Museum Facilities Administrators (IAMFA) meeting/lecture/event at the BA with Chief Conservator and Facilities Director, other historic houses/museums.

## **Evaluation**

IPI's report *Mechanical System Analysis and Optimization* provides an extensive evaluation of the project. Moreover, their conclusions drawn from the data were further confirmed by analysis of the systems by Boston Athenæum staff, specifically, Chris Silva.

## **Continuation of the Project**

As stated in the Observations, Recommendations, Actions section. We hope to pursue an implementation grant for updating the interior lighting and the purchase and installation of additional window coverings.

## **Long Term Impact**

IPI's report and the arrival of the Boston Athenæum's new Director of Facilities, Chris Silva, prompted a comprehensive examination of the systems, and inaugurated a series of near term and long term solutions to the problems that were unearthed. These solutions are largely outlined in the Short and Long Term Recommendations sections.